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Mr. William F. Caton, Acting Secretary
Federal Communications Commission
1919 M Street, N.W., Room 222
Washington, D.C. 20554

Dear Mr. Caton:

Enclosed are ten copies of three Errata pages which we request be inserted in our Reply Comments in the Matter of Revision of Part 22 and Part 90 of the Commission's Rules to Facilitate Future Development of Paging Sytems (WT Docket No. 96-18).

These Errata were necessary because earlier versions of our work product were incorporated into the Reply Comments which was filed with your office yesterday, April 2, 1996. These changes do not affect the recommendations and conclusions contained in the Reply Comments.

For the Commission's convenience, we have included ten copies of the complete Reply Comments as amended in this Errata so that pages do not have to be inserted.

Should you have any questions concerning this, please do not hesitate to contact our office.

Sincerely yours,

Arthur K. Peters, P.E.

AKP:pjl
Enclosures
cc: Mr. Sam Gumbert (w/encls.)

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Revision of Part 22 and Part 90 of the Commission's Rules to Facilitate Future Development of Paging Systems	)	WT Docket No. 96-18
	)	
Implementation of Section 309(j) of the Communications Act – Competitive Bidding	)	PP Docket No. 93-253

TO: The Commission

REPLY COMMENTS ERRATA

Arthur K. Peters, P.E.
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Gainesville, Florida 32605
Phone: (352) 331-0149

Filed: April 3, 1996

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INTRODUCTION

The firm of Arthur K. Peters, Consulting Engineers, is submitting these Reply Comments in response to numerous comments filed in this Docket; specifically in response to a number of issues which were raised by Ameritech Mobile Services, Inc. and others.

One of Ameritech's basic premises was that the Commission should retain its existing definitions of service and interference distances presented in the Rules as Tables E1 and E2. We fundamentally disagree with that approach to spectrum management. Efficient spectrum management requires a rational allocation process based on need and actual service and interfering signal levels. We agree with Ameritech that the FCC's management techniques must ensure that paging services are protected from interference to a technically reasonable extent. To obtain maximum spectrum efficiency, it is important that real-world conditions are accounted for in the allocation of spectrum and that the same consideration be given to interference protection requirements. It is to this issue that these Reply Comments are directed. This document includes a proposal to manage the 930 MHz paging spectrum in a manner similar to that currently used by the FCC in the lower frequency bands, but based on solid propagation data.

HISTORICAL BACKGROUND

In the early 1960's, when mobile and paging began to grow rapidly, there was a dirth of information and data available to administer and efficiently manage the paging and mobile spectrum which had been made available. In 1964, Roger B. Carey of the FCC published an analysis in Report R6406, "Technical Factors Affecting the Assignment of Facilities in the Domestic Public Land Mobile Radio Service" which adapted the 1963 CCIR curves (Recommendation No. 370) for use with the DPLRMS services. The CCIR curves were based on receiving antenna heights of ten metres and were adjusted by 9 dB to reflect a 6-foot receiving antenna height. An analysis to determine the proper signal strength which would provide reliable service and the signal strength which would provide an interfering signal level were determined by Carey. The process used by Carey was technically sound and is used here to determine service and interference contour values.

The National Bureau of Standards, in May, 1965, published what is considered by many to be the definitive work in propagation prediction techniques. This work, the product of Philip L. Rice, A.G. Longley, K.A. Norton and A.P. Barsis, was assigned the title of Technical Note 101 and was subsequently revised in 1966 and 1967. The report utilized thousands of long-term and short-term propagation measurements from the entire world. These measurements were analyzed to produce systematic signal level prediction techniques for the most diverse set of conditions ever presented in such a report. Because of it's great diversity, the large number of variables involved in determining a signal level made the utilization of Tech Note 101 a major effort. For that reason, many people simply turned to other methods of analysis. Principally, they retained the very simplistic techniques enumerated by Kenneth Bullington in the late 1940's and 1950's.

In 1968, Okumura, et al., published a paper based on measurements taken in the Tokyo vicinity. It is this data that the FCC is proposing to adopt as "official" for use in the United States, and, in particular, for use with 930 MHz paging in this Docket. In the course of normal business, I have had an opportunity to discuss the Okumura studies with Japanese engineers who were involved in the project. The Okumura study was initiated because engineers "in the trenches" simply did not understand the highly complex Technical Note 101. They would have preferred to utilize Tech Note 101 but simply could not "get it to work." Most engineers faced the same dilemma.

In 1979, the National Telecommunications and Information Administration, Institute for Telecommunications Sciences, produced a computer implementation of Technical Note 101 which is entitled The Longley-Rice Model — An Implementation, 1979, by George A. Hufford. This implementation greatly simplified the operation of Tech Note 101 while retaining many of its capabilities. The Hufford implementation represented a great breakthrough in the utilization of possibly the world's best prediction method.

In the mid-1970's, the firm of Arthur K. Peters had produced its own implementation of Tech Note 101 which gave similar results as the Hufford approach but which required a great deal more input data and considerably greater brain strain. Hufford simplified the entire process and we rapidly adopted his techniques. Hufford's significant accomplishments form the technical bases for the recommendations which we offer in this proceeding.

WHAT IS BEING PROPOSED

We are proposing here, for 930 MHz Paging, to utilize simple exponential equations similar to those already currently utilized by the FCC in other bands. The exponential curves have been derived using the National Bureau of Standards (NBS) Tech Note 101 as implemented by Hufford. We will show that Okumura curves are inappropriate for use by spectrum managers. We also desire to convince the reader that the FCC should adopt the NBS implementation by Hufford as the underlying basis for the management of 930 MHz paging equations.

We present a determination of the reliable service contour and a definition of the interference contour which substantially deviates from those proposed by the FCC in this Docket's NPRM.

Comparisons of the proposed FCC formulae against CCIR (Carey), NBS and Okumura curves are presented. It is shown that the FCC equations do not closely match any of those characteristic families of propagation curves. Obviously, the exponential equations of the form adopted by the FCC are desirable because they are easy to implement using hand calculators and unsophisticated computers. In an ideal world the equations should exactly predict the field strength over a wide range of cases. Because of the complexity of propagation curves, this cannot be readily achieved. Engineers facing this dilemma rely upon a piece-wise analysis to describe small portions of data such as those grouped around the service and interference contours. None of the equations produces an absolutely accurate representation but they are sufficiently accurate to utilize as spectrum management tools. The equations below have been carefully tuned to reflect the adopted NBS data.

OKUMURA CURVES ARE INAPPROPRIATE FOR USE BY THE FCC

Okumura, et al. produced a good paper with an able analysis of variabilities of various kinds which are typically involved in signal propagation. Unfortunately, the Okumura study is extremely limited in its range of situations and has no provision for determining long-term signal variability. Simply, the Okumura study suffers from comparatively few measurements taken over very limited numbers of mobile courses. Okumura states that his goal was to produce a set of urban attenuation characteristics which were applicable to terrain conditions found in Japan. He indicates that the CCIR and other published propagation predictions did not apply in Japan where "terrain is complicated and irregular". For those very same reasons, the measurements taken by Okumura should be considered parochial and applicable only to the Tokyo environs. There is no evidence to indicate that they can be expanded to other places around the world for which terrain situations, building situations and other impediments to propagation might differ from those found in the Tokyo region.

Okumura's measurements were carefully performed over several different "mobile courses" using signals from several transmitting locations, each transmitting on several frequencies. From these measurements, a set of statistics were generated and presented in the 1969 report. In contrast, the NBS measurement data included virtually all of the published measurement data from the entire world. A significant majority of the data were from U.S. workers. The NBS data was both long-term and short-term and its measured data and statistical analysis provides for long-term variabilities, necessary for interference determinations.

The Okumura measurements do not have any long-term measurements and thus knowledge of the fields ten percent of the time cannot be obtained from Okumura.

The Okumura measurements were made in two 3-month periods and produced no weather related differences. The weather characteristics in Tokyo would be significantly different from those encountered in Salt Lake City or Gainesville, Florida. A complete set of relations which can give a relatively high confidence level must include such factors.

CAREY CURVES ARE INAPPROPRIATE

The original CCIR curves adapted by Carey are inappropriate for use in this Docket because they cannot really be adapted to the paging situation where the receiver antenna height is typically about one metre. The height gain factor of 9 dB which Carey applied to the CCIR curves is not necessarily applicable at 930 MHz and 1 metre antenna heights. Our experience suggests the factor is significantly different.

NBS (HUFFORD) DATA IS PREFERRED

Previously, any set of curves which were presented by the FCC and used for spectrum management and allocations were subject to individual interpretations. For example, how to treat the antenna height when it falls between curves. The NBS Tech Note 101 approach not only provides the requisite accuracy due to a solid foundation of measured data, it produces an analytic result. It produces repeatable results and everyone obtains the same result given identical input. The Hufford program code is freely available and included in the Hufford implementation available from NTIS. Using the computer implementation as the final authority, a great administrative burden would be removed due to lack of disputes over interpolated values within a set of graphical curves.

The NBS data can be used in a wide variety of situations and be adapted for various climates which occur within the jurisdiction of the FCC such as Alaska, the Virgin Islands and the desert Southwest. (Using more than one climate should be the subject of a future FCC investigation. It is recommended that the NBS program be used with a continental temperate climate and other fixed factors for which application of the program will produce identical results by everyone.)

The range of the NBS propagation program is impressive. The program automatically accounts for isolated knife-edge obstacles, non-isolated single horizon obstacles, double horizon obstacles, line-of-sight propagation and scatter propagation. Single horizon and double horizon paths are computed automatically. (One form of the program is also capable of using digital terrain elevation data, although this would normally not be used for spectrum allocations.) The program will operate from 20 to 20,000 MHz over distances from 1 to 2,000 kilometres. Antenna heights can range from one-half wave length at the frequency of interest to 10,000 metres. Surface refractivity's between 250 and 400 and terrain roughness factors between 0 and 500 metres will encompass virtually every weather condition and terrain characteristic on the planet. Several different climates are incorporated which have been partitioned to account for virtually all of the climates in the world.

The statistical analysis incorporated in the Hufford program enables determination, among other factors, of the time fading factor which has been used in this document to determine recommended service and interference contour values. The time fading factor is simply the difference in dB between the median expected signal strength and the signal strength which will occur 10% of the time. This value is normally a function of distance and will be discussed below.

The firm of Arthur K. Peters has had considerable experience measuring field strengths in a variety of situations which span various operating powers and frequencies. The results of the NBS predictions appear to be well within our experience for 930 MHz paging systems currently being deployed. That is, the NBS predictions seem realistic and reasonable.

GENERAL NBS ASSUMPTIONS

All of the NBS calculations employed in these Comments have consistently used several assumptions. These include transmitter and receiver sites at random locations. That is, neither base stations nor receivers have any preferential position, on the average. Although this may not be true for base stations in general, for administrative purposes it represents conservative estimates.

The system ground elevations at both receive and transmit sites were uniformly set to zero. This eliminates the compensation that the program provides for different refractive indexes when the receiver and transmitters are located at substantially different elevations.

The terrain roughness factor was set to 50 metres. A continental temperate climate was used which is generally acceptable over the entire United States. Ground constants were taken as average using a conductivity of 5 mS/m with a dielectric constant of 15. The program was operated in a broadcast mode in order to enable separate control of percentage of time and percentage of locations. Unless otherwise noted, median values of time and location were utilized in the presentation of all graphs.

In comparing Okumura curves with the NBS curves, it was decided to use a consistent approach throughout and utilize the NBS data with a receive antenna height of 1 metre. The Okumura curves utilize a receiver height of 1.5 metres. Okumura indicates that the difference between 1.5 and 1 metre receive heights would be approximately 1 dB, which is not significant in this analysis. Carey data was utilized from the curves given in R-6406.

Some of the plotted curves look rather segmented. This is not due to data but simply due to the number of data points used to define the various curves. In an effort to meet the tight submission deadline, a limited number of points were read from each of the data sets. Hence the polygon look of some of the curves. Again, this does not detract from the overall accuracy of the analysis. Where greater accuracy was required, sparse data points were frequently supplemented.

Figure 1 is a plot of F(50,50) and F(50,10) curves obtained from the Hufford implementation of NBS Tech Note 101. Also included is a free space inverse field curve at 930 MHz. The data for these curves appears in tabular form in the appendix and can be supplemented should anyone desire.

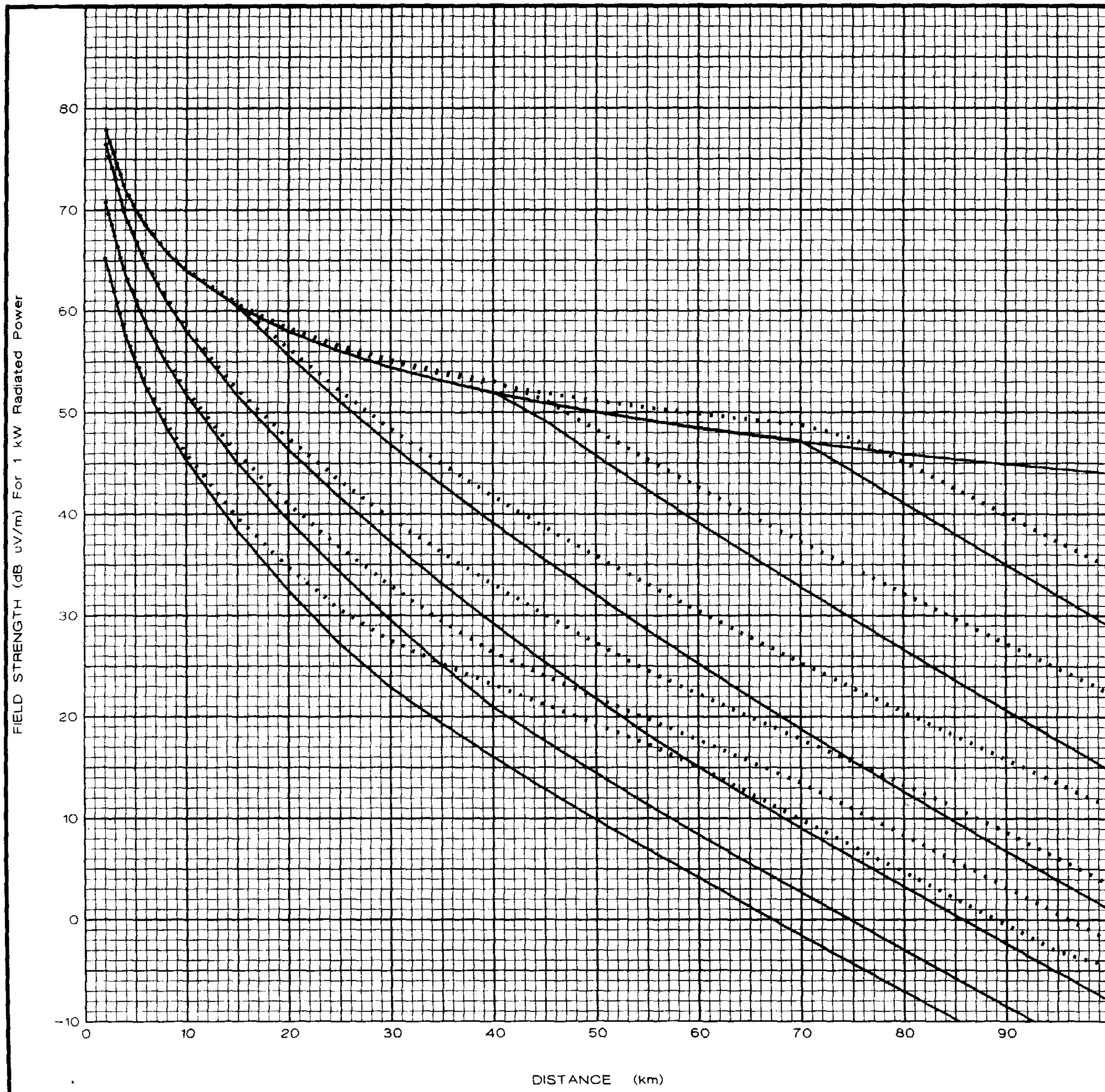
The curves of Figure 1 form the basis for the entire analysis which follows.

COMPARISONS OF VARIOUS DATA SETS

Comparisons are presented, for informational purposes only, to illustrate the degree of similarity and differences between Carey, Okumura and NBS. They have no other purpose except as a sanity check on the current process.

Figure 2 compares the Carey against the Okumura curves. The Carey curves are obviously high by a number of dB. Interestingly, the Okumura curves go above free space for high antennas. Okumura shows a different rate of attenuation and a slightly different height gain factor for low antenna heights. This may be due to Okumura's concentration on urban areas.

Figure 3 compares the NBS with the Carey curves. A similar situation occurs with the Carey curves because they were not prepared from 930 MHz data and used a 9 dB scaling factor.



WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

NBS F(50,50) and F(50,10)
Basis for determining Tu (Time fading factor)

Free Space
30 m NBS F(50,50)
70 m F(50,50)
150 m F(50,50)
300 m F(50,50)
600 m F(50,50)
1000 m F(50,50)
30 m NBS F(50,10)
70 m F(50,10)
150 m F(50,10)
300 m F(50,10)
600 m F(50,10)
1000 m F(50,10)

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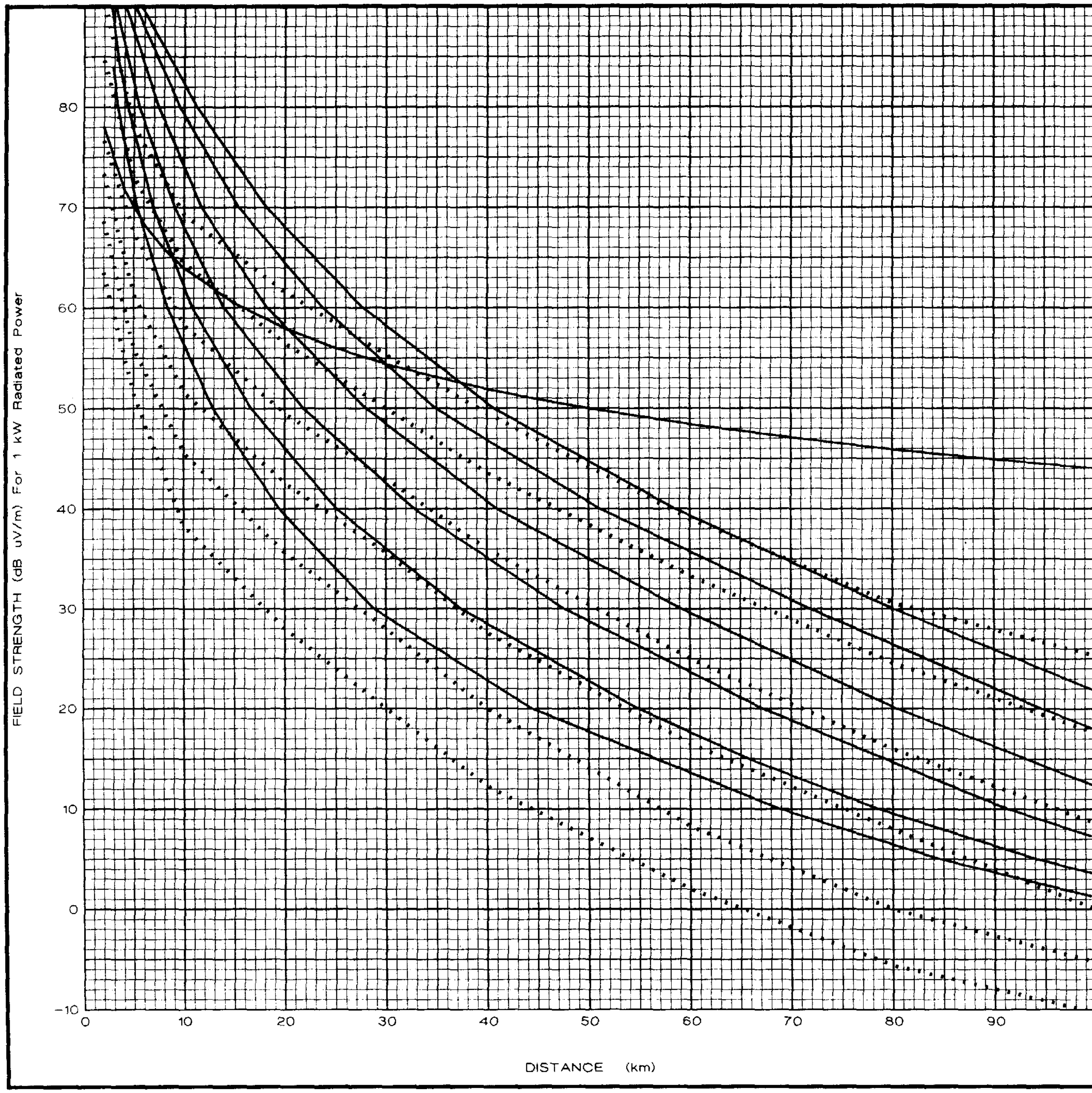
960402 ARTHUR K. PETERS Figure 1



WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

Carey vs Okumura F(50,50)

Free Space
30m Carey (CCIR 370,1963)
70 m
150 m
300 m
600 m
1000 m
30 m Okumura Fig 41c Rx=1.5m
70 m
150 m
300 m
600 m
1000 m

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960402 ARTHUR K. PETERS Figure 2

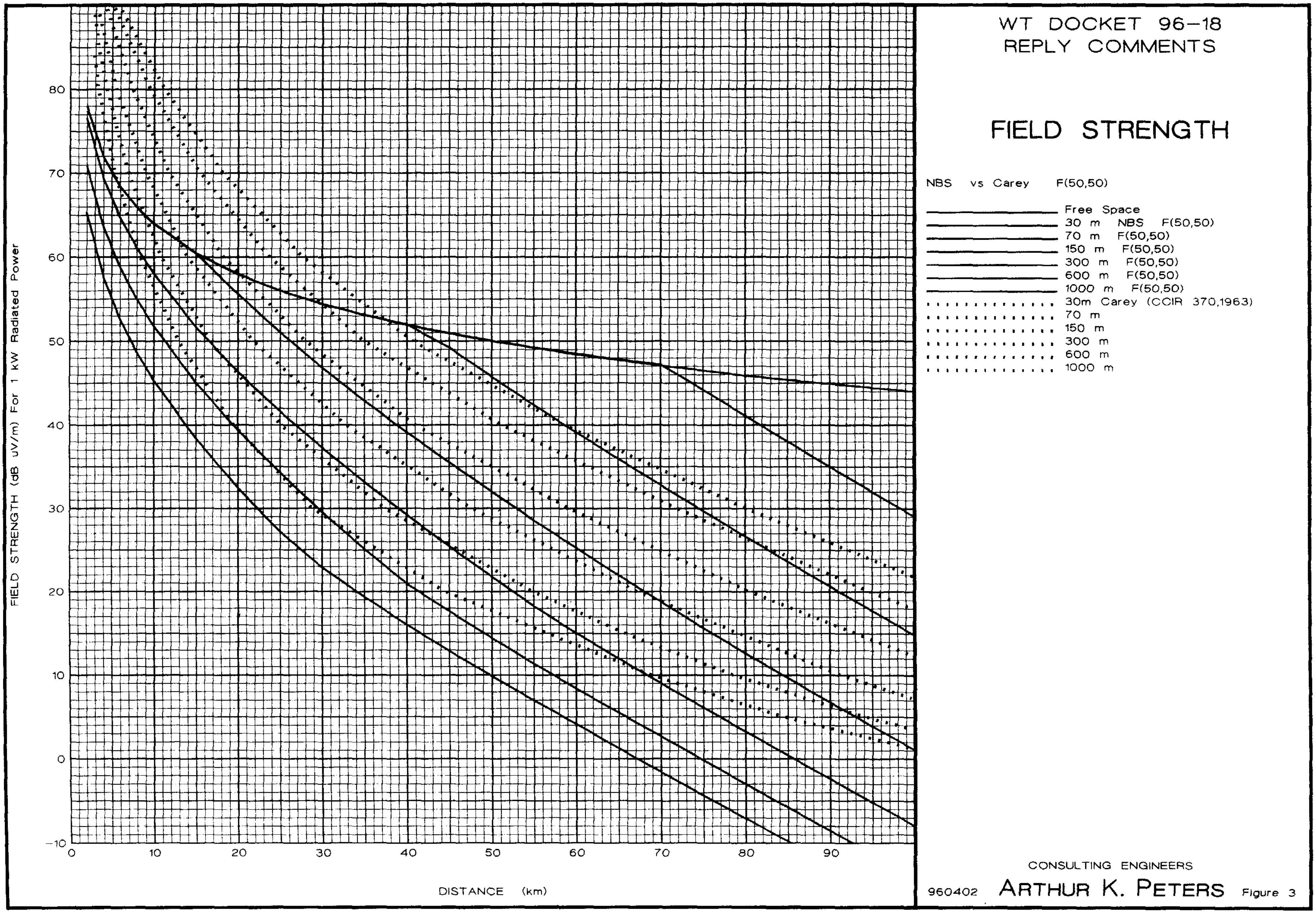
WT DOCKET 96-18
REPLY COMMENTS
FIELD STRENGTH
NBS vs Carey F(50,50)
Free Space
30 m NBS F(50,50)
70 m F(50,50)
150 m F(50,50)
300 m F(50,50)
600 m F(50,50)
1000 m F(50,50)
30m Carey (CCIR 370,1963)
70 m
150 m
300 m
600 m
1000 m
FIELD STRENGTH (dB uV/m) For 1 kW Radiated Power
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
DISTANCE (km)
CONSULTING ENGINEERS
960402
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Figure 3

Figure 4 plots the NBS data against the Okumura data. There is a closer correlation here than with the previous comparisons. This is likely due to the fact that the Okumura curves were measured at 922 MHz. The correlation is also a positive indication that the NBS curves are reasonable, and vice-versa.

OKUMURA vs. FCC FORMULAE

Figure 5 is a graph on which the Okumura curves have been plotted. To illustrate the match between the proposed FCC formulae and the Okumura curves upon which they are based, we have plotted the FCC data using dashed curves. Also plotted on the graph is an inverse field (free space) curve which illustrates the free space field strength at 930 MHz.

The comments which follow should not be construed as criticism, but simply as an analysis of the information on the graph. It is recognized that it is very difficult to obtain a piece-wise formula which matches closely all of the curves over large ranges of values. The dashed lines from the FCC formulae do not correspond very closely to the Okumura curves.

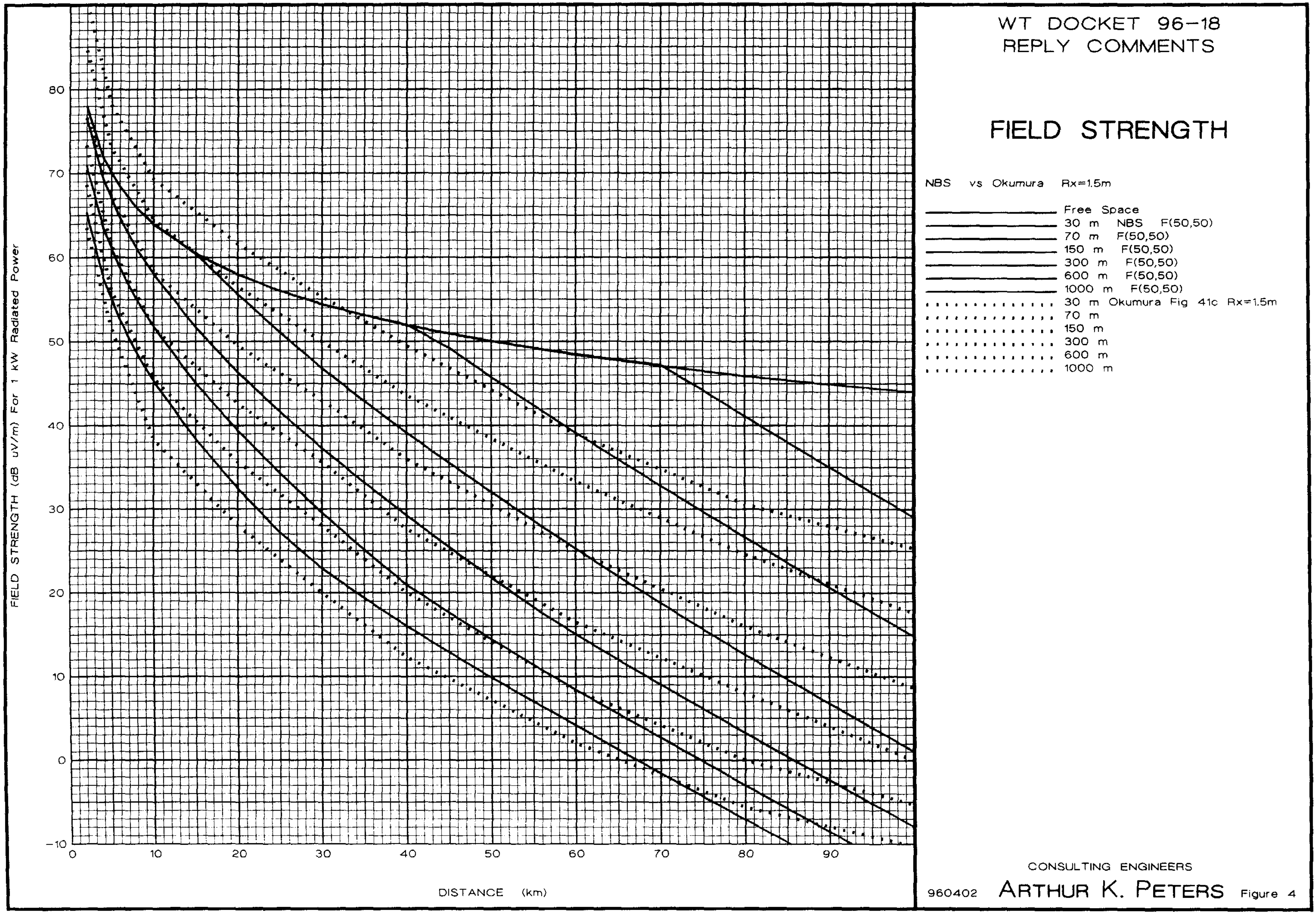
This is a moot point since we have already recommended that the Okumura curves not be used by the FCC.

CAREY vs. FCC FORMULAE

As a curiosity, we tested the FCC formulae against the Carey curves. As expected, there is an irreparable difference between the two as shown in Figure 6.

NBS vs. FCC FORMULAE

In Figure 7, the FCC formulae are compared with the NBS curves. As seen here, there is a visual similarity to the NBS curves. The range of values of the FCC curves are on the same order of magnitude as NBS curves for many of the antenna heights. It could be possible to adjust the FCC formulae to match these curves. In fact, that is what we have done below.



WT DOCKET 96-18
REPLY COMMENTS
FIELD STRENGTH
NBS vs Okumura Rx=1.5m
Free Space
30 m NBS F(50,50)
70 m F(50,50)
150 m F(50,50)
300 m F(50,50)
600 m F(50,50)
1000 m F(50,50)
30 m Okumura Fig 41c Rx=1.5m
70 m
150 m
300 m
600 m
1000 m
FIELD STRENGTH (dB uV/m) For 1 kW Radiated Power
80
70
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
80
90
DISTANCE (km)
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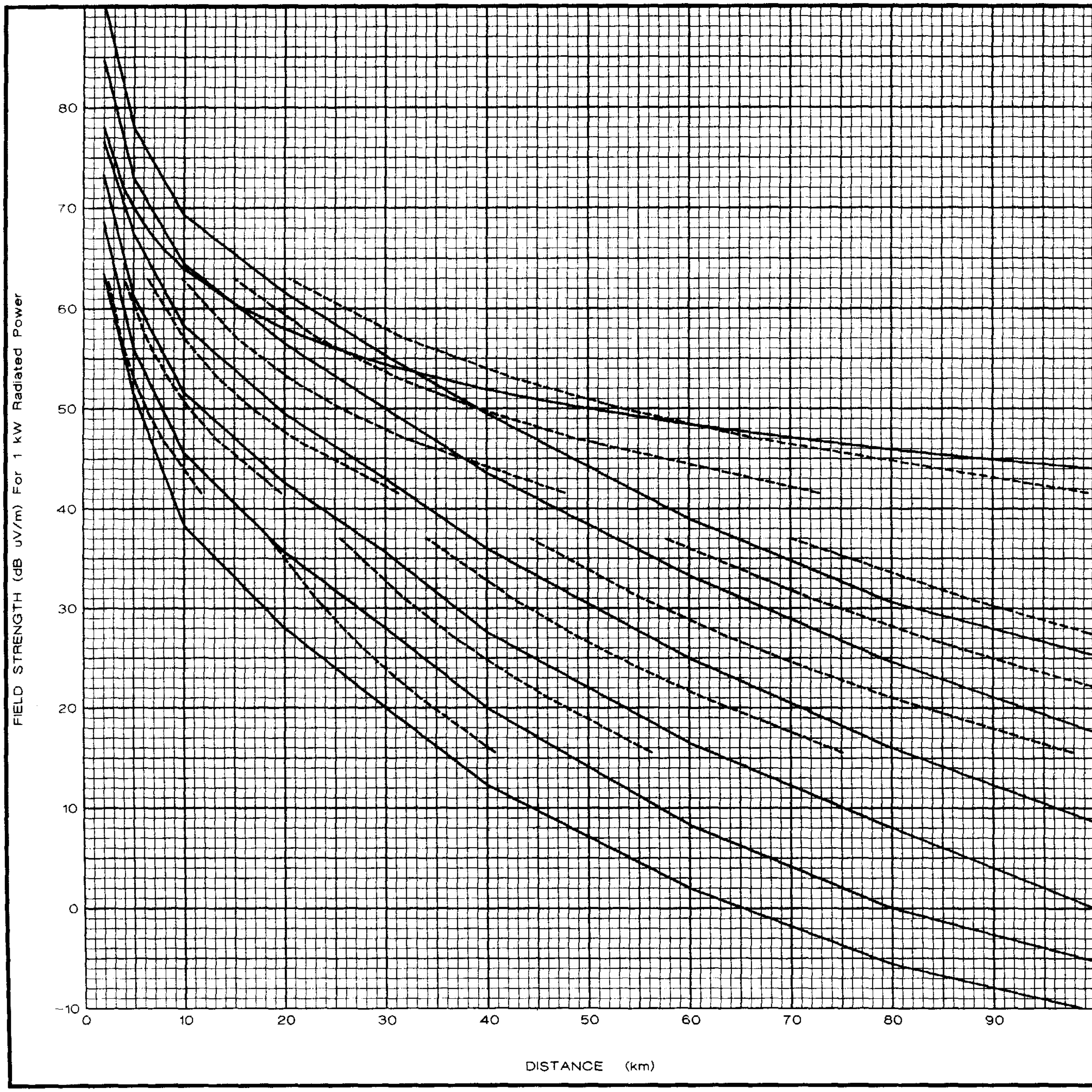
960402 ARTHUR K. PETERS Figure 4



WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

Okumura vs FCC Formulae

Free Space
30 m Okumura Fig 41c Rx=1.5m
70 m
150 m
300 m
600 m
1000 m
FCC 47dBu @ 30m
FCC 47dBu @ 70m
FCC 47dBu @ 150m
FCC 47dBu @ 300m
FCC 47dBu @ 600m
FCC 47dBu @ 1000m
FCC 21dBu @ 30m
FCC 21dBu @ 70m
FCC 21dBu @ 150m
FCC 21dBu @ 300m
FCC 21dBu @ 600m
FCC 21dBu @ 1000m

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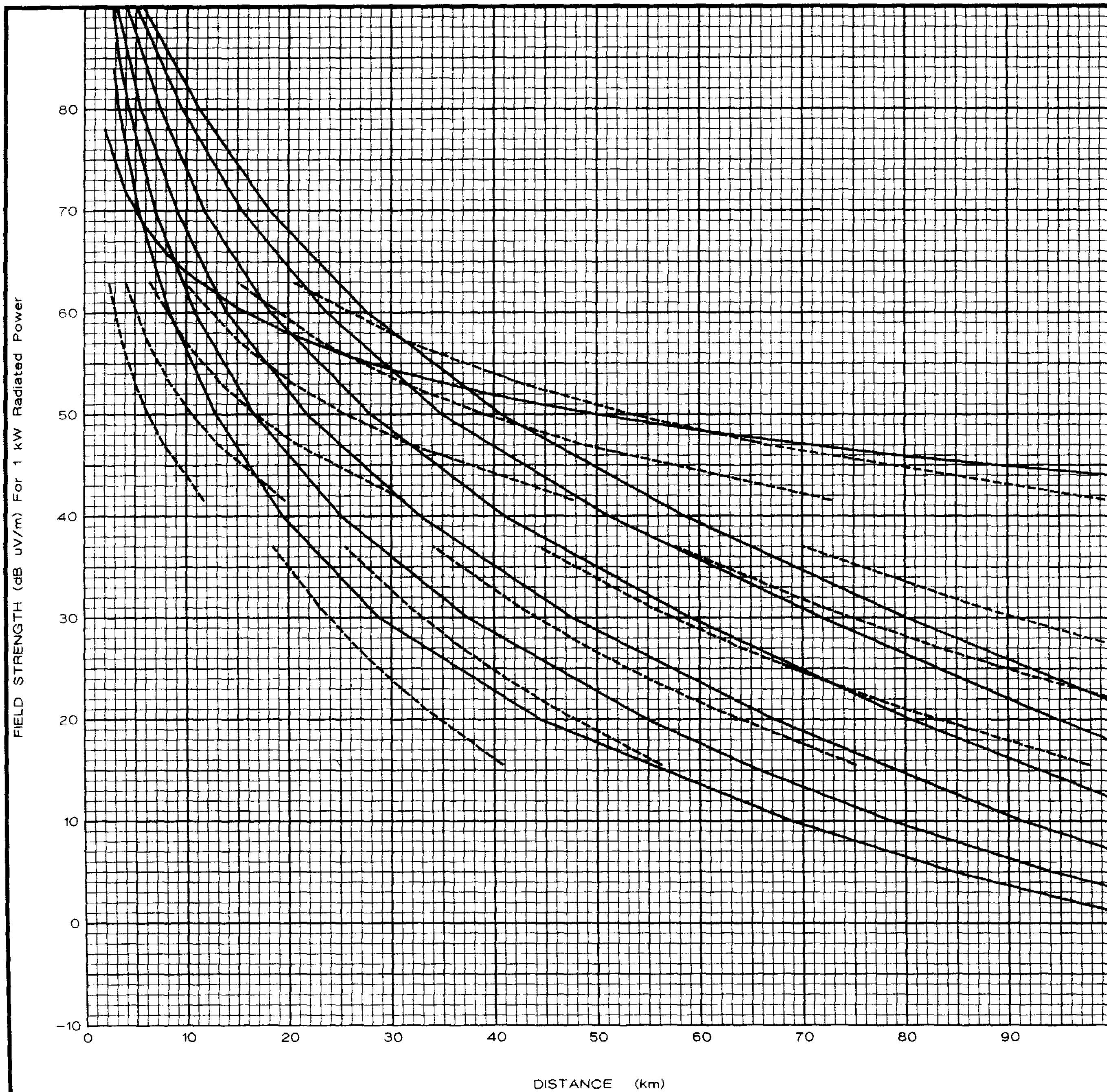
960402 ARTHUR K. PETERS Figure 5



WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

Carey vs FCC Formulae

Free Space
30m Carey (CCIR 370,1963)
70 m
150 m
300 m
600 m
1000 m
FCC 47dBu @ 30m
FCC 47dBu @ 70m
FCC 47dBu @ 150m
FCC 47dBu @ 300m
FCC 47dBu @ 600m
FCC 47dBu @ 1000m
FCC 21dBu @ 30m
FCC 21dBu @ 70m
FCC 21dBu @ 150m
FCC 21dBu @ 300m
FCC 21dBu @ 600m
FCC 21dBu @ 1000m

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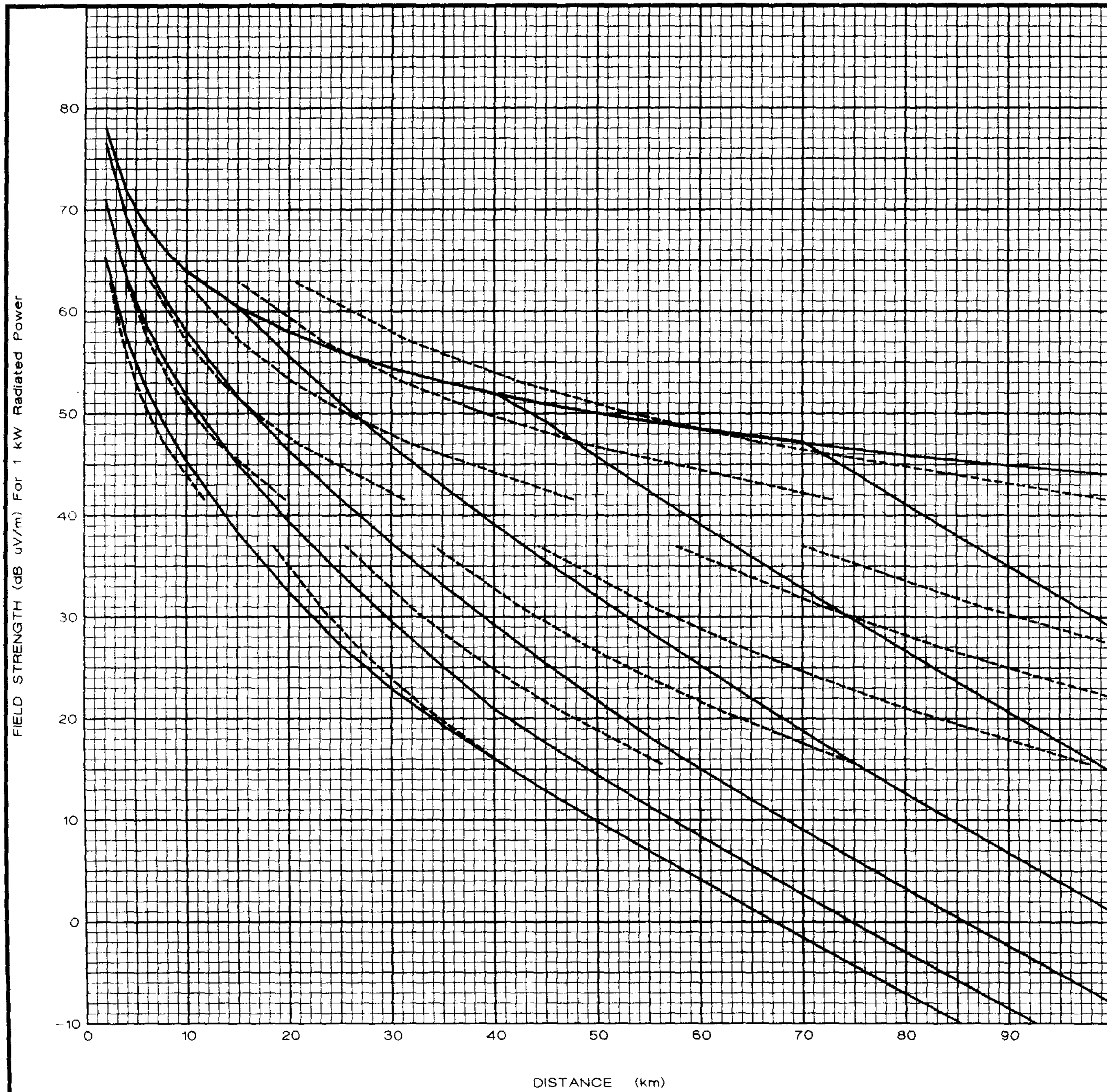
960402 ARTHUR K. PETERS Figure 6

WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

NBS vs FCC Formulae

- Free Space
- 30 m NBS F(50,50)
- 70 m F(50,50)
- 150 m F(50,50)
- 300 m F(50,50)
- 600 m F(50,50)
- 1000 m F(50,50)
- FCC 47dBu @ 30m
- FCC 47dBu @ 70m
- FCC 47dBu @ 150m
- FCC 47dBu @ 300m
- FCC 47dBu @ 600m
- FCC 47dBu @ 1000m
- FCC 21dBu @ 30m
- FCC 21dBu @ 70m
- FCC 21dBu @ 150m
- FCC 21dBu @ 300m
- FCC 21dBu @ 600m
- FCC 21dBu @ 1000m



CONSULTING ENGINEERS

960402 ARTHUR K. PETERS Figure 7

SERVICE AND INTERFERENCE CONTOUR LEVEL DERIVATION

Several variables must be established and assumptions made before a determination of the signal level required for service and the signal level which defines interference are obtained. For example, we have assumed that the short-term fading signal follows a log normal distribution and has a standard deviation of 8 dB. This standard deviation is relatively common and used by many workers. It could possibly be lowered slightly but that would not be a conservative position.

We have assumed a paging receiver threshold field strength of 10 µV/m which corresponds to a field of 20 dBu. We have also assumed that a 90% paging reliability is mandatory within the service contour. This corresponds to 90% of the locations 90% of the time. A carrier-to-interference minimum acceptance ratio (A) is assumed to be 11 dB which yields a Frequency Shift Keying (FSK) bit error rate of approximately 10^{-3}.

To determine a ratio between desired and undesired signals we have followed the Bullington statistical combination of factors enumerated in Carey.

The C/I ratio R becomes

$$R = A + K\,(L_d^2 + L_u^2 + T_u^2)^{1/2} \qquad (1)$$

K (90%)	=	1
L_d (90%)	=	1.282 x 8 = 10.3 dB
L_u (10%)	=	-1.282 x 8 = -10.3 dB

T_u was derived by obtaining the maximum difference between the NBS F(50,50) and F(50,10) curves. As mentioned earlier, the T_u factor is distance-dependent but has an interesting characteristic in that for each antenna height, the value of T_u reaches a maximum value at some given distance. All of the maximum values for all the antenna heights are nearly equal; but occur at different distances. In our case, T_u is found to be 12 dB at a distance of between 90 and 100 kilometres for an antenna height of 30 metres. At an antenna height of 300 metres, the maximum difference is also 12 dB, but occurs at a much greater distance. (For the interested reader, these characteristics are plotted in Figures 10 and 26 of FCC Report R6602.) The 12 dB value may also be obtained from the tabular data (see Appendix) by subtracting the NBS F(50,50) value at 30 metres at 100 kilometres from the value of the F(50,10) curve at the same distance and height. Using 12 dB as a fixed value (not distance sensitive) is conservative. Signal variability increases with distance, so assuming an interferor's variability is at its maximum for all distances is conservative with respect to interference protection. Moreover, T_u = 12 dB is reasonable.

The factors L_u and L_d are included to provide assurances that the desired signal is 90% reliable and that the undesired signal is that signal level which occurs less than or equal to 10% of the time. Obviously, if the interfering signal occurred more than 10% of the time then the desired signal could not obtain 90% reliability. Placing the factors in equation (1) yields a desired-to-undesired ratio of

$$D/U = 29.9 \text{ dB} = 11 + 1((10.3)^2 + (-10.3)^2 + (12)^2)^{1/2} \approx 30 \text{ dB}$$

We assumed a desired-to-undesired ratio of 30 dB. Currently the FCC uses a ratio of 26 dB at 450 MHz. The value of 30 dB at 930 MHz appears reasonable.

The signal level at the limit of the reliable service area can be derived in any number of ways, some of which are quite esoteric. However, a relatively simple method is to determine the difference between the NBS F(50,50) curves and the desired F(90,90) curves. This gives a factor which moves the reliability from 50% to 90%. The NBS program was again used to compute the difference in dB at a radius of 50 kilometres. F(50,50) and F(90,90) values are tabulated in the Appendix. At 50 kilometres with an antenna height of 30 metres an F(50,50) field strength of 9.9 dBu is obtained as is an F(90,90) value of -8.7 dBu. The difference in these values is 18.6 dB. We have used 19 dB as the factor by which the receiver threshold must be increased in order to be assured of a 90% reliability. An antenna height of 30 metres was used because the difference between F(50,50) and F(50,90) decreases with antenna height. Thus, the conservative value occurs at 30 metres. 50 kilometres was selected by determining, using the NBS program, the distance to the 30 metres F(50,10) contour at the maximum power, 3500 Watts. The maximum power was adjusted by 9 dB which is the difference between F(90,90) data at 50% confidence and 90% confidence. This yields a distance of 40 kilometres, which was conservatively rounded up to 50 kilometres. This convoluted approach was taken to ensure that a reliable definition of the service contour is selected. Confidence in this context means that in 90% of all paging systems, a signal level which is 19 dB greater than a receiver's threshold will correctly decode its message 90% of the time at 90% of all locations within the defined service contour. Adding 19 dB to the receiver threshold of 20 dBu yields a service contour value of 39 dBu.

If our desired-to-undesired signal ratio, as derived above, is subtracted from 39 dBu, the interfering signal level at the 39 dBu contour must be no greater than

9 dBu. Since the interfering signal has already been adjusted to 10% values, the F(50,50) curves are used for determining both service and interference distances.

To test the values just derived, assume an antenna height of 300 metres and an ERP of 1 kW. The distance to the 39 dBu contour equals 40 kilometres (24.9 miles) and the distance to the interfering contour equals 86 kilometres (53.4 miles). At 30 metres and 1 kW the distance to the 39 dBu contour is 15.1 kilometres (9.3 miles) and the distance to the interfering contour is 51.5 km (32 miles). These values are, in our experience, very close to those which are realized in practical systems. They also match quite well the current tabular values in the FCC Rules.

Therefore we recommend a service contour value of 39 dBu as applied to the NBS F(50,50) curves of Figure 1 using the assumptions stated above. The desired-to-undesired minimum ratio is recommended to be 30 dB.

FITTING FORMULAE TO NBS CURVES

Two sets of data were obtained by reading the graph of Figure 1. This produced a pair of tables for the 39 and 9 dBu contours respectively. Tables 1 and 2 show the values used to obtain the exponents of the equations which have the form

$$\text{Distance} = B \quad (\text{Height})^{x} \quad (\text{ERP})^{y}$$

Where the height is in metres and ERP in Watts.

ERP		Distance to 39 dBu Field (km)						
dBk	Watts	Height (m)	30	70	150	300	600	1000
5.44	3500		19.0	26.0	34.7	47.8	68.7	92.3
0.00	1000		15.1	20.3	28.1	40.1	60.3	83.4
-3.01	500		12.8	18.0	24.8	36.3	55.7	78.4
-10.00	100		7.8	12.2	17.7	27.4	44.8	56.7
-16.02	25		5.1	8.0	12.6	20.7	28.3	28.3

TABLE 1 — Service Contours, 39 dBu using NBS F(50,50) Curve Data

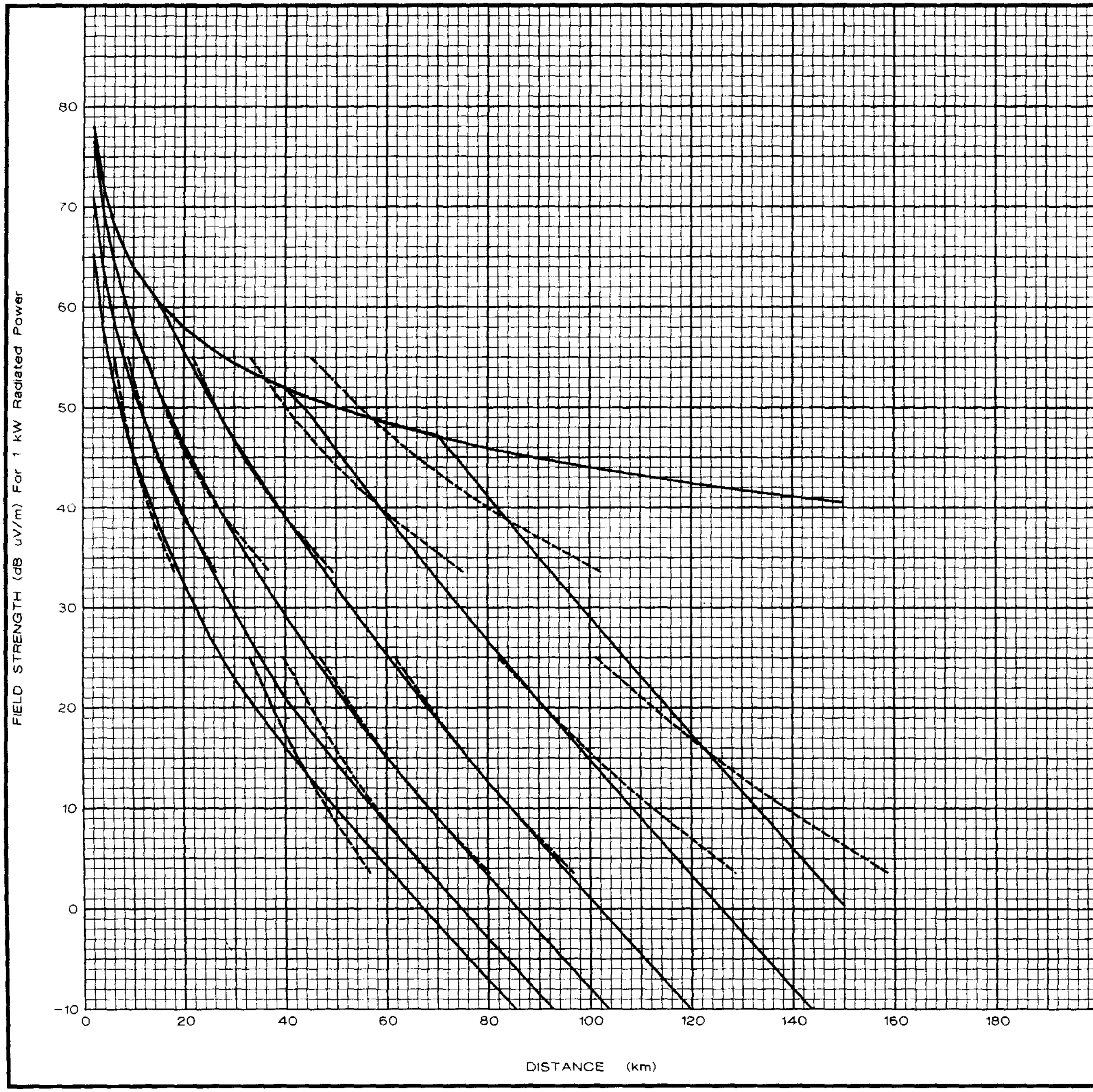
ERP			Distance to 9 dBu Field (km)					
dBk	Watts	Height (m)	30	70	150	300	600	1000
5.44	3500		61.0	68.7	79.5	95.6	119.5	144.6
0.00	1000		51.6	59.0	70.0	86.2	110.0	135.0
-3.01	500		46.7	54.2	65.2	81.2	105.0	129.6
-10.00	100		41.7	49.3	54.2	69.7	92.8	117.3
-16.02	25		27.8	35.3	45.7	60.4	82.8	106.8

TABLE 2 — Interference Contours, 9 dBu Using NBS F(50,50) Curve Data

It was noticed during the analysis that a natural break occurred in the data in the vicinity of an antenna height of 200 metres. To ensure the best fit, the problem was divided into two parts and the coefficients were then determined for each pair of equations. Figure 8 shows the fit of the resulting equations to the NBS F(50,50) curves. In general, the fit is reasonably accurate. In those places where the formulae deviate from the NBS curves, there is a tendency to overstate distances, principally at the higher antenna heights. Antenna heights up to approximately 400 metres appear to be in reasonable agreement with the curves for both the service and interference contours. At low antenna heights, 30 and 70 metres, and low radiated powers, the formulae overestimate the distance to the interference contour by less than two kilometres. For a regulatory agency this would be conservative. A low antenna height (30 metres) with very high power tends to understate the interfering contour distance by two kilometres out of 60 kilometres. Similar analyses can be performed by observing the discrepancies on Figure 8 between the formulae and the NBS curves.

In all cases, each of the height curves shown on Figures 5 through 9 has an ERP range of 25 Watts to 3500 Watts.

Some of the problems with the fit of the formulae can be attributed to the desire to match the sets of curves above and below 200 metres. Figure 9 is the same as Figure 8 but additional curves have been included at 199 metres and 200 metres. These clearly identify the discontinuity occurring between the formulae. One might opt for a single formula for the entire height range, which we attempted, but were unsuccessful at obtaining as close a match to the curves as



WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

Shows fit of proposed formulae to NBS F(50,50)

Free Space
30 m NBS F(50,50)
70 m F(50,50)
150 m F(50,50)
300 m F(50,50)
600 m F(50,50)
1000 m F(50,50)
39 dBu 30 m
39 dBu 70 m
39 dBu 150 m
39 dBu 300 m
39 dBu 600 m
39 dBu 1000 m
9 dBu 30 m
9 dBu 70 m
9 dBu 150 m
9 dBu 300 m
9 dBu 600 m
9 dBu 1000 m

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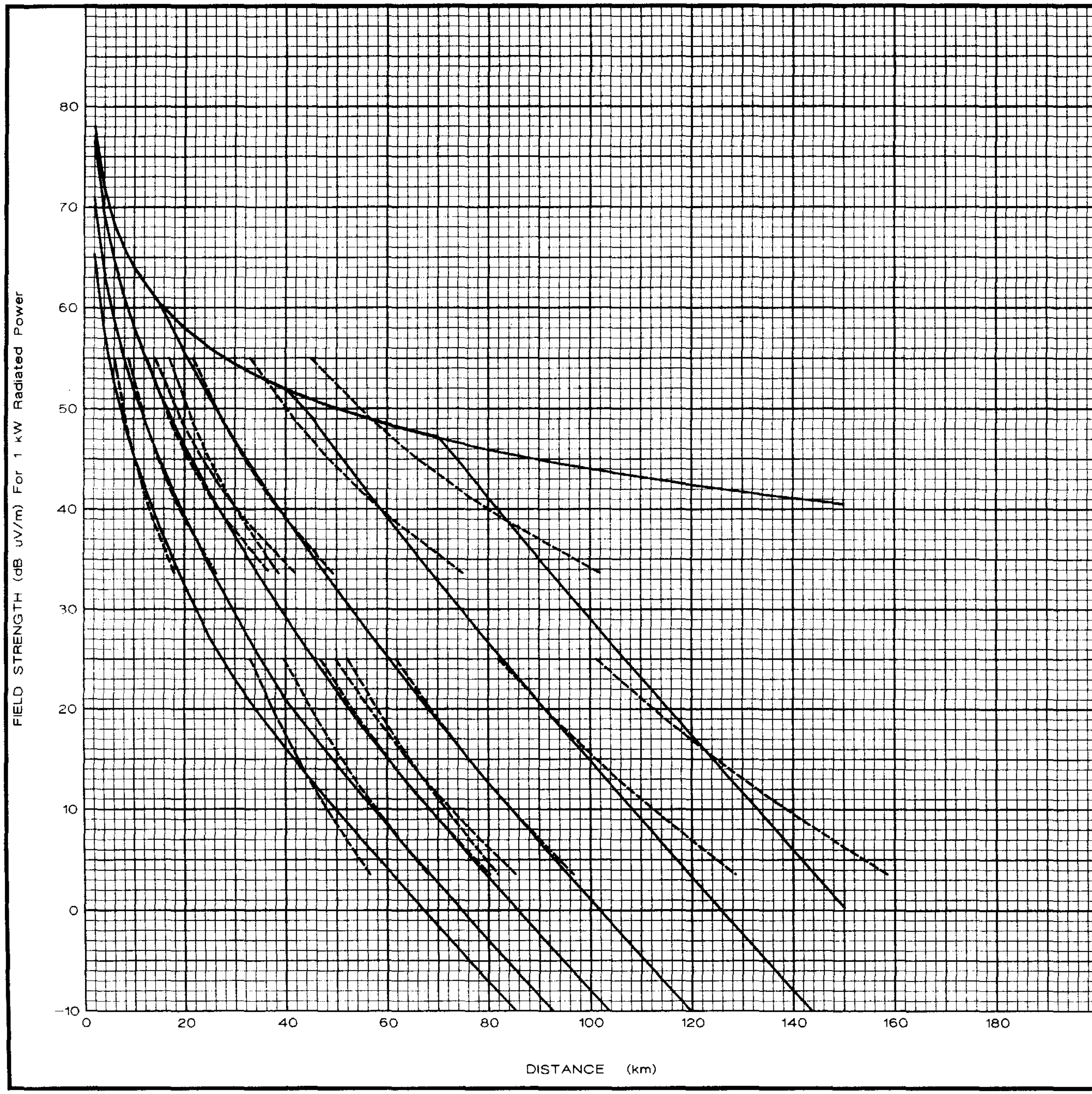
960402 ARTHUR K. PETERS Figure 8



WT DOCKET 96-18
REPLY COMMENTS

FIELD STRENGTH

Shows fit of proposed formulae to NBS F(50,50)
Curves for 199m and 200m show formulae transitions

Free Space
30 m NBS F(50,50)
70 m F(50,50)
150 m F(50,50)
300 m F(50,50)
600 m F(50,50)
1000 m F(50,50)
39 dBu 30 m
39 dBu 70 m
39 dBu 150 m
39 dBu 300 m
39 dBu 600 m
39 dBu 1000 m
9 dBu 30 m
9 dBu 70 m
9 dBu 150 m
9 dBu 300 m
9 dBu 600 m
9 dBu 1000 m
39 dBu 199 m
39 dBu 200 m
9 dBu 199 m
9 dBu 200 m

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960402 ARTHUR K. PETERS Figure 9

with two height ranges. The final versions of the formulas produce these service and interference equations:

For Antenna Heights Less than 200 metres:

$$\text{Service Contour Distance} = 0.666 \times H^{(0.445)} \times ERP^{(0.219)}$$

$$\text{Interference Contour Distance} = 11.114 \times H^{(0.217)} \times ERP^{(0.109)}$$

For Antenna Heights equal to or greater than 200 metres:

$$\text{Service Contour Distance} = 0.404 \times H^{(0.605)} \times ERP^{(0.166)}$$

$$\text{Interference Contour Distance} = 4.415 \times H^{(0.411)} \times ERP^{(0.091)}$$

Where H = metres and ERP = Watts

CONCLUSIONS

If the FCC adopted the NBS curves as implemented by Hufford, they would obtain, for the first time, a method to analytically determine field strengths for a large range of situations. Even if the FCC adopted a single situation by which to compute the curves, the work done here could be of great assistance to the efficient utilization of staff time. The time required to compute a set of curves using Hufford's implementation, in a computer which runs at 50 MHz, is virtually instantaneous. That is, once the input is finished the actual computations require a very short time.

The formulae derived here appear to be reasonable in our experience. Some factors in this analysis might need modification. For example, our use of the receiver threshold field strength of 10 µV/m is one area which could require modification. The use of a 11 dB acceptance ratio yielding an FSK BER of 10^{-3} could be modified as required. Any changes in the assumptions regarding service contour and interference contour values should be met with a review of the formula fits to the NBS curves.

There is a natural tendency for engineers to "twiddle" once they gain access to a program which is as diverse as Hufford's implementation of Technical Note 101. If the FCC adopts this proposal, it would be well advised to carefully define each of the input parameters when used for official purposes. This is easily done as the number of parameters is not great and can be easily specified without ambiguity. For example, one could use only continental temperate climates for official purposes. "Unofficial" users could benefit by using a climate closer to their actual climate when determining losses in their local areas.

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April 2, 1996